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SUBJECT: Forwards "summary of failure modes & effects analysis of ECCS.No single failure identified more damaging than previously described in USAR.W/six oversize drawings.

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H. B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2
DOCKET NO. 50-261/LICENSE NO. DPR-23
EMERGENCY CORE COOLING SYSTEM (ECCS) FAILURE MODES
AND EFFECTS ANALYSIS (FMEA) SUMMARY INFORMATION

Gentlemen:

The NRC letter dated March 17, 1989 required Carolina Power & Light Company (CP&L) to provide a written submittal outlining measures taken or planned to assure that the H. B. Robinson Steam Electric Plant, Unit No. 2 (HBR2) complies with the single worst failure requirement of 10CFR50.46 and Appendix K. CP&L's letter dated May 19, 1989 outlined the plan to perform a Failure Modes and Effects Analysis (FMEA) to reevaluate the Emergency Core Cooling System (ECCS) and ensure that the acceptance criteria of 10CFR50.46 are met in accordance with the single failure criterion of Appendix K.

The FMEA has been completed; no single failure was identified which was more damaging than those previously described in the Updated Safety Analysis Report. Preliminary results of this study were presented in a meeting on November 20, 1990. A summary of the FMEA is enclosed for your review. The complete study is available at our Raleigh office for your inspection.

Questions regarding this matter may be referred to Mr. R. W. Prunty at (919) 546-7318.

Yours very truly,

G. E. Vaughn

G. E. Vaughn, having been first duly sworn, did depose and say that the information contained herein is true and correct to the best of his information, knowledge and belief; and the sources of his information are officers, employees, contractors, and agents of Carolina Power & Light Company.

Eleanor C. Chappell
Notary (Seal)

My commission expires:
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ELEANOR C. CHAPPELL NOTARY PUBLIC WAKE COUNTY, N.C.

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Enclosure

cc: Mr. S. D. Ebneter
Mr. L. Garner (NRC-HBR)
Mr. R. Lo

TABLE OF CONTENTS

1.0 INTRODUCTION

This report presents the Single Failure Analysis (SFA) for the Robinson Nuclear Project (RNP) Emergency Core Cooling System (ECCS). A Failure Mode and Effects Analysis (FMEA) evaluated the ECCS vulnerability to postulated single component failures to determine if such failures could cause the loss of the ECCS capability during pre-accident ECCS standby operations, the post-accident ECCS short-term injection phase and the long-term recirculation phase. The report also evaluated the ECCS vulnerability to the effects of flooding caused by system leakage during the recirculation phase.

2.0 SUMMARY AND CONCLUSIONS OF ANALYSIS RESULTS

2.1 FAILURE MODE AND EFFECTS ANALYSIS SUMMARY

The failure mode and effects analysis (FMEA) worksheets identified 118 potential single point system vulnerabilities that required further evaluation to determine if the postulated component failures could impact ECCS readiness during pre-accident standby operations or could cause the ECCS not to achieve the required post-accident minimum performance requirements during the short-term ECCS injection phase or during the long-term ECCS recirculation phase. Table 2.1 presents a listing of the 118 potential areas of system vulnerability and the final disposition for each potential area of vulnerability. None of the 118 areas of ECCS single point vulnerability were classified as applicable ECCS single point failures for reasons noted in the table.

2.2 LOCALIZED FLOODING ASSESSMENT

The ECCS equipment is located in the auxiliary building, RHR pump pit, containment, and the RWST area outside of the auxiliary building. Postulated ECCS system leaks up to 50 gpm during the recirculation phase were evaluated for the RHR pump pit to determine if the leak would cause localized flooding conditions that disabled equipment required for ECCS operation. For the auxiliary building, assumed leakage was based on quantities normally anticipated from seals, flanges, valve stems, etc., but no leakage due to a passive single failure was assumed in order to be consistent with NRC guidance and the plant's original design basis.

The analysis disclosed that system leakage inside containment did not have any effect on ECCS operation during the recirculation phase. In addition, system leakage in the RWST area during the recirculation phase was not considered credible because the RWST is isolated from all active ECCS flow paths.

ECCS leakage in the RHR pump pit will ultimately flood the pit, disable both RHR pumps and all ECCS operation during the recirculation phase. A modification installed during Refueling Outage 13 (1990-1991) provides for remotely detecting and isolating RHR pump pit ECCS and support system leaks with equipment qualified to operate in the post-accident environment. After the leak has been isolated, one RHR pump will remain operational.

2.3 CONCLUSIONS

Although Robinson Nuclear Project was designed and constructed prior to issuance of many of the current standards and General Design Criteria, the ECCS system stands up very well under the evaluation of this Single Failure Analysis. This analysis did not identify a single failure that was more damaging than those previously analyzed and described in the UFSAR.

TABLE 2.1. POTENTIAL SINGLE POINT ECCS VULNERABILITIES

No.	Component Description	Failure Mode	Notes
	Air Operated Valves		8
1	FCV-605	Fail open	1,2
2	SI-850A	External leakage	3
3	SI-850B	External leakage	3
4	SI-850C	External leakage	3
5	SI-850D	External leakage	3
6	SI-850E	External leakage	3
7	SI-850F	External leakage	3
8	SI-851A	External leakage	3
9	SI-851B	External leakage	3
10	SI-851C	External leakage	3
11	SI-852A	Fail open	3
12	SI-852A	External leakage	3
13	SI-852B	Fail open	3
14	SI-852B	External leakage	3
15	SI-852C	Fail open	3
16	SI-852C	External leakage	3
17	SI-853A	External leakage	3
18	SI-853B	External leakage	3
19	SI-853C	External leakage	3
20	SI-856A	Fail Closed	16
21	SI-856B	Fail Closed	16
	Motor Operated Valves		9
22	SI-862A	Fail closed	1,2
23	SI-862B	Fail closed	1,2
24	SI-863A	Fail open	1,2

TABLE 2.1. POTENTIAL SINGLE POINT ECCS VULNERABILITIES (CONT.)

No.	Component Description	Failure Mode	Notes
	Motor Operated Valves (Cont.)		9
25	SI-863B	Fail open	1,2
26	SI-864A	Fail closed	1,2
27	SI-864B	Fail closed	1,2
28	SI-865A	Fail closed	1,2
29	SI-865A	External leakage	3
30	SI-865B	Fail closed	1,2
31	SI-865B	External leakage	3
32	SI-865C	Fail closed	1,2
33	SI-865C	External leakage	3
34	SI-868A	Fail closed	1,2
35	SI-868B	Fail closed	1,2
36	SI-868C	Fail closed	1,2
37	SI-869	Fail closed	1,2
38	SI-878A	Fail closed	1,2
	Check Valves		11
39	SI-839	Failure to open	4
40	SI-873A	Failure to open	4
41	SI-873B	Failure to open	4
42	SI-873C	Failure to open	4
43	SI-873D	Failure to open	4
44	SI-873E	Failure to open	4
45	SI-873F	Failure to open	4
46	SI-874A	Failure to open	4

TABLE 2.1. POTENTIAL SINGLE POINT ECCS VULNERABILITIES (CONT.)

No.	Component Description	Failure Mode	Notes
	Check Valves (Cont.)		11
47	SI-874B	Failure to open	4
48	SI-875A	Failure to open	4
49	SI-875A	External leakage	3
50	SI-875B	Failure to open	4
51	SI-875B	External leakage	3
52	SI-875C	Failure to open	4
53	SI-875C	External leakage	3
54	SI-875D	Failure to open	4
55	SI-875D	External leakage	3
56	SI-875E	Failure to open	4
57	SI-875E	External leakage	3
58	SI-875F	Failure to open	4
59	SI-875F	External leakage	3
60	SI-876A	Failure to open	4
61	SI-876A	External leakage	3
62	SI-876B	Failure to open	4
63	SI-876B	External leakage	3
64	SI-876C	Failure to open	4
65	SI-876C	External leakage	3
66	SI-877A	External leakage	3
67	SI-877B	External leakage	3
68	SI-877C	External leakage	3
69	SI-879A	Failure to close	4

TABLE 2.1. POTENTIAL SINGLE POINT ECCS VULNERABILITIES (CONT.)

No.	Component Description	Failure Mode	Notes
	Check Valves (Cont.)		11
70	SI-879B	Failure to close	4
71	SI-879C	Failure to close	4
	Relief Valves		12
72	SI-858A	Failure to close	3
73	SI-858A	External leakage	3
74	SI-858B	Failure to close	3
75	SI-858B	External leakage	3
76	SI-858C	Failure to close	3
77	SI-858C	External leakage	3
	Manual Valves		13
78	RHR-743	Fail closed	1,2
79	RHR-764	Fail closed	1,2
80	SI-881A	External leakage	3
81	SI-881B	External leakage	3
82	SI-881C	External leakage	3
83	SI-881D	External leakage	3
84	SI-881E	External leakage	3
85	SI-881F	External leakage	3
86	SI-881G	External leakage	3
87	SI-881H	External leakage	3
88	SI-881J	External leakage	3
89	SI-881K	External leakage	3

TABLE 2.1. POTENTIAL SINGLE POINT ECCS VULNERABILITIES (CONT.)

No.	Component Description	Failure Mode	Notes
	Manual Valves (Cont.)		13
90	SI-881L	External leakage	3
91	SI-881M	External leakage	3
92	SI-882A	External leakage	3
93	SI-882B	External leakage	3
94	SI-882C	External leakage	3
95	SI-883B	External leakage	3
96	SI-883C	External leakage	3
97	SI-883E	External leakage	3
98	SI-883F	External leakage	3
99	SI-883H	External leakage	3
100	SI-883J	External leakage	3
101	SI-884A	External leakage	3
102	SI-884B	External leakage	3
103	SI-884C	External leakage	3
104	SI-884D	External leakage	3
105	SI-884E	External leakage	3
106	SI-884F	External leakage	3
107	SI-891C	Fail open	1,2
108	SI-891D	Fail open	1,2
109	SI-895K	Fail open	1,2
	Pumps		14
110	SIPB	Buses E1 and E2 cross tied	1,2

TABLE 2.1. POTENTIAL SINGLE POINT ECCS VULNERABILITIES (CONT.)

No.	Component Description	Failure Mode	Notes
	Vessels		15
111	RWST	Blocked vent	6
112	SI Accumulator A	Fluid inventory high	7
113	SI Accumulator A	External leakage	3
114	SI Accumulator B	Fluid inventory high	7
115	SI Accumulator B	External leakage	3
116	SI Accumulator C	Fluid inventory high	7
117	SI Accumulator C	External leakage	3
	Hand Control Valves		10
118	HCV-758	Fail open	1,2

Notes:

1. Failure is not considered credible as discussed in Section 5.
2. Operating procedures preclude failure mode when plant is operating at power or during ECCS operation.
3. Failure propagates SI accumulator pressure and/or level decay which is immediately alarmed. Prompt corrective action is taken per the Tech Spec requirements.
4. The check valve periodic testing program provides the basis for exempting the check valves from consideration as potential active ECCS single point failures.
5. The valve operability is verified quarterly during SI pump testing. If the valve motor does not open the valve prior to the start of the recirculation phase, procedures require the operator to open the valve locally using the valve handwheel.
6. Passive failures are not considered valid ECCS failures during ECCS standby operation or during the injection phase per NRC guidance.
7. Failure initiates high level alarm before operating limit is reached. Prompt corrective action is taken per Tech Spec if operating limit is exceeded.
8. See Section 5.1 for discussion of ECCS vulnerability to air operated valve failures.
9. See Section 5.2 for discussion of ECCS vulnerability to motor operated valve failures.
10. See Section 5.3 for discussion of ECCS vulnerability to hand control valve failures.
11. See Section 5.5 for discussion of ECCS vulnerability to check valve failures.
12. See Section 5.6 for discussion of ECCS vulnerability to relief valve failures.
13. See Section 5.7 for discussion of ECCS vulnerability to manual valve failures.
14. See Section 5.9 for discussion of ECCS vulnerability to pump failures.
15. See Section 5.11 for discussion of ECCS vulnerability to vessel failures.
16. Reactor depressurization is rapid enough so that injection flow is achieved prior to any damage to HPSI pumps.

3.0 SCOPE OF ANALYSIS

Section 3.0 defines the components that are within the scope of the RNP ECCS SFA. The ECCS flow diagrams were reviewed to define the applicable components. The applicable flow diagrams attached were highlighted to identify those components and line segments within the analysis scope. The ECCS components were evaluated by a failure mode and effects analysis (FMEA) as part of the ECCS SFA.

Section 3.1 presents the annotated flow diagrams that define the boundary of the evaluation. Section 3.2 presents the listing of ECCS components.

3.1 ANNOTATED FLOW DIAGRAMS

Annotated flow diagrams are attached. The annotation defines the boundary of the ECCS evaluation. These boundary limits define the scope of the ECCS component list presented in Section 3.2. In general, all components with an SI tag number are enveloped by the scope of the SFA. The most significant deviation from this general rule is the Containment Spray System (CSS). The CSS is not an active element of the ECCS, however, it can have an impact on ECCS operation due to the effect of containment backpressure. The conservatism in the ECCS thermal hydraulic analyses took no credit for operation or non-operation of the CSS to reduce ECCS flow requirements. With the exception of four CSS valves, CSS components were not included within the scope of this SFA. The four CSS valves SI-880A, B, C, and D were included in the scope of analysis because ECCS End Path Procedure 9 requires the valves to be closed before the start of the recirculation phase.

Systems that interface with, and support the ECCS components (e.g., Service Water System, Liquid Radwaste System, Primary Sampling System, Chemical and Volume Control System, Spent Fuel Pool Cooling System, Emergency Power Distribution System, etc.), are also excluded from the ECCS SFA scope.

3.2 COMPONENT LIST

Table 3-1 presents a listing of ECCS components that were evaluated by a FMEA as part of the ECCS SFA.

This listing only includes the components identified on the flow diagrams. Control circuit components (e.g., switchgear, circuit breakers, fuses, bistables, relays, switches, limit switches, and torque switches) for electromechanical components (e.g., MOVs, AOVs, pumps) that are identified on the applicable component control wiring diagrams (CWDs) are within the FMEA scope. Panel status lamps and dropping resistors, that only provide indication, are not within the FMEA scope unless during the development of the FMEA it was determined that their failure directly impacts another circuit component.

Instrumentation was included from bistable devices out to the control circuits of active ECCS components. Instrumentation (e.g., indicators and transmitters) shown on the flow diagrams is not within the scope of the FMEA evaluation. Instrumentation root valves to a single instrument, provided there are no additional branch lines from the instrumentation line shown on the flow diagrams, and provided that there is no control or interlock function with other ECCS components, are also not within the scope of the FMEA evaluation because the failure effect of these valves is enveloped by the FMEA of the associated instrument. However, root valves that could isolate more than a single instrument were evaluated by the FMEA.

All manual drain, vent, sample, test connection and flush line isolation valves shown on the flow diagrams, that are not manually stroked during ECCS operation, are also not within the scope of the FMEA. The only applicable failure mode for these valves is external leakage. This passive failure (external leakage) is enveloped by the analysis of the line segments during the recirculation phase.

To provide assurance that all SI-related components were addressed by the SFA, all applicable components are identified in Table 3-1. Components that are exempted from the FMEA are identified and the justification for the exemption is provided by Table 3-1 notes.

The evaluation of power sources for ECCS components consider only from the bus side of the breaker and do not consider "a" and "b" aux contacts that interface with hardware outside of the ECCS component envelope.

TABLE 3-1. COMPONENT LIST

TAG NO.	DRAWING NO.	SHEET NO.	DRAWING ZONE	NOTES
AIR OPERATED VALVES				
FCV-605	5379-1484	1	D7	
SI-841A	5379-1082	1	E3	1,6
SI-841B	5379-1082	1	E2	1,6
SI-850A	5379-1082	4	E3	
SI-850B	5379-1082	4	F4	
SI-850C	5379-1082	4	E3	
SI-850D	5379-1082	4	E4	
SI-850E	5379-1082	4	D3	
SI-850F	5379-1082	4	C4	
SI-851A	5379-1082	5	E5	
SI-851B	5379-1082	5	D5	
SI-851C	5379-1082	5	B5	
SI-852A	5379-1082	5	E7	
SI-852B	5379-1082	5	D7	
SI-852C	5379-1082	5	B7	
SI-853A	5379-1082	5	G6	
SI-853B	5379-1082	5	E6	
SI-853C	5379-1082	5	C6	
SI-855	5379-1082	5	F3	
SI-856A	5379-1082	2	D3	
SI-856B	5379-1082	2	E3	

TABLE 3-1. COMPONENT LIST (CONT.)

TAG NO.	DRAWING NO.	SHEET NO.	DRAWING ZONE	NOTES
MOTOR OPERATED VALVES				
RHR-744A	5379-1484	1	B8	
RHR-744B	5379-1484	1	B8	
RHR-750	5379-1484	1	B2	1, 13
RHR-751	5379-1484	1	B2	1, 13
RHR-752A	5379-1484	1	D3	14
RHR-752B	5379-1484	1	F3	14
RHR-759A	5379-1484	1	D7	
RHR-759B	5379-1484	1	F7	
SI-860A	5379-1082	5	C2	
SI-860B	5379-1082	5	B2	
SI-861A	5379-1082	5	C2	
SI-861B	5379-1082	5	B2	
SI-862A	5379-1082	2	B3	
SI-862B	5379-1082	2	B3	
SI-863A	5379-1082	2	C3	
SI-863B	5379-1082	2	C3	
SI-864A	5379-1082	2	E4	
SI-864B	5379-1082	2	E4	
SI-865A	5379-1082	4	F2	
SI-865B	5379-1082	4	D2	
SI-865C	5379-1082	4	C2	
SI-866A	5379-1082	4	D7	
SI-866B	5379-1082	4	D7	
SI-867A	5379-1082	1	D3	
SI-867B	5379-1082	1	C3	
SI-868A	5379-1082	1	B7	10
SI-868B	5379-1082	1	B7	10

TABLE 3-1. COMPONENT LIST (CONT.)

TAG NO.	DRAWING NO.	SHEET NO.	DRAWING ZONE	NOTES
MOTOR OPERATED VALVES (CONT.)				
SI-868C	5379-1082	1	B6	10
SI-869	5379-1082	1	F7	
SI-870A	5379-1082	1	D8	
SI-870B	5379-1082	1	D7	
SI-878A	5379-1082	2	D7	
SI-878B	5379-1082	2	E7	
SI-880A	5379-1082	3	C5	
SI-880B	5379-1082	3	C5	
SI-880C	5379-1082	3	E5	
SI-880D	5379-1082	3	E5	
HAND CONTROL VALVES				
HCV-758	5379-1484	1	E8	
HCV-936	5379-1082	5	E3	
PRESSURE CONTROL VALVES				
PCV-937	5379-1082	5	F2	
CHECK VALVES				
RHR-753A	5379-1484	1	D5	
RHR-753B	5379-1484	1	F5	
RHR-762A	5379-1484	1	E3	
RHR-762B	5379-1484	1	F3	
RHR-774	5379-1484	1	E4	
RHR-775	5379-1484	1	E4	
SI-839	5379-1082	2	D4	
SI-849	5379-1082	4	F7	

TABLE 3-1. COMPONENT LIST (CONT.)

TAG NO.	DRAWING NO.	SHEET NO.	DRAWING ZONE	NOTES
CHECK VALVES (CONT.)				
SI-873A	5379-1082	4	C6	
SI-873B	5379-1082	4	C6	
SI-873C	5379-1082	4	C5	
SI-873D	5379-1082	4	B6	
SI-873E	5379-1082	4	B6	
SI-873F	5379-1082	4	B5	
SI-874A	5379-1082	4	C7	
SI-874B	5379-1082	4	C7	
SI-875A	5379-1082	4	B6	
SI-875B	5379-1082	4	B7	
SI-875C	5379-1082	4	A7	
SI-875D	5379-1082	4	F3	
SI-875E	5379-1082	4	D3	
SI-875F	5379-1082	4	C3	
SI-876A	5379-1082	4	F3	
SI-876B	5379-1082	4	D4	
SI-876C	5379-1082	4	C3	
SI-877A	5379-1082	4	F2	
SI-877B	5379-1082	4	E2	
SI-877C	5379-1082	4	C2	
SI-877D	5379-1082	1	C4	
SI-879A	5379-1082	2	C7	
SI-879B	5379-1082	2	E7	

TABLE 3-1. COMPONENT LIST (CONT.)

TAG NO.	DRAWING NO.	SHEET NO.	DRAWING ZONE	NOTES
CHECK VALVES (CONT.)				
SI-879C	5379-1082	2	F7	
SI-889C	5379-1082	2	C4	
SI-893A	5379-1082	2	D6	
SI-893B	5379-1082	2	E6	
SI-893C	5379-1082	2	G6	
SI-894	5379-1082	1	C4	
SI-909	5379-1082	5	F3	
RELIEF VALVES				
RHR-706	5379-1484	1	B8	
SI-857A	5379-1082	1	F7	
SI-857B	5379-1082	1	C8	
SI-858A	5379-1082	5	F5	
SI-858B	5379-1082	5	E5	
SI-858C	5379-1082	5	C5	
SI-859	5379-1082	4	F8	
MANUAL VALVES				
RHR-743	5379-1484	1	C7	
RHR-745A	5379-1484	1	C6	1,2
RHR-745B	5379-1484	1	C5	1,2
RHR-754A	5379-1484	1	D5	
RHR-754B	5379-1484	1	F5	
RHR-755A	5379-1484	1	E5	
RHR-755B	5379-1484	1	F5	
RHR-756A	5379-1484	1	D5	

TABLE 3-1. COMPONENT LIST (CONT.)

TAG NO.	DRAWING NO.	SHEET NO.	DRAWING ZONE	NOTES
MANUAL VALVES (CONT.)				
RHR-756B	5379-1484	1	F5	
RHR-757A	5379-1484	1	D6	
RHR-757B	5379-1484	1	F6	
RHR-757C	5379-1484	1	E5	
RHR-757D	5379-1484	1	F5	
RHR-760	5379-1484	1	E7	
RHR-761A	5379-1484	1	D8	1,2
RHR-761B	5379-1484	1	D8	1,2
RHR-764	5379-1484	1	E8	
RHR-766A	5379-1484	1	D4	1,4
RHR-766B	5379-1484	1	F4	1,4
RHR-766C	5379-1484	1	D4	1,4
RHR-766D	5379-1484	1	E4	1,4
RHR-767A	5379-1484	1	D5	1,3
RHR-767B	5379-1484	1	E5	1,3
RHR-767C	5379-1484	1	E3	1,9
RHR-767D	5379-1484	1	F3	1,9
RHR-771A	5379-1484	1	D6	1,3
RHR-771B	5379-1484	1	F6	1,3
RHR-771C	5379-1484	1	D6	1,3
RHR-771D	5379-1484	1	F6	1,3
RHR-772A	5379-1484	1	E4	1,3
RHR-772B	5379-1484	1	E5	1,3
SI-836B	5379-1082	5	F2	1,2
SI-837	5379-1082	2	E4	1,3,11
SI-838A	5379-1082	2	A6	1,4

TABLE 3-1. COMPONENT LIST (CONT.)

TAG NO.	DRAWING NO.	SHEET NO.	DRAWING ZONE	NOTES
MANUAL VALVES (CONT.)				
SI-838B	5379-1082	2	A6	1,4
SI-838C	5379-1082	2	A6	1,2
SI-838D	5379-1082	2	A6	1,4
SI-838E	5379-1082	2	A6	1,4
SI-838F	5379-1082	2	A6	1,2
SI-838G	5379-1082	2	A6	1,4
SI-838H	5379-1082	2	A6	1,4
SI-838I	5379-1082	2	A6	1,2
SI-841C	5379-1082	1	E3	1,3,6
SI-841D	5379-1082	1	E3	1,4,6
SI-843	5379-1082	2	D4	1,3
SI-847	5379-1082	5	F2	
SI-854A	5379-1082	4	D8	1,2
SI-854B	5379-1082	4	E8	1,2
SI-854C	5379-1082	4	D7	1,2
SI-854D	5379-1082	4	E7	1,2
SI-856D	5379-1082	2	D4	1,4
SI-873H	5379-1082	4	C6	1,3
SI-873J	5379-1082	4	C5	1,3
SI-873K	5379-1082	4	E6	1,3
SI-873L	5379-1082	4	D6	1,4
SI-874C	5379-1082	4	C7	1,4
SI-874D	5379-1082	4	C8	1,4
SI-874E	5379-1082	4	F7	1,4

TABLE 3-1. COMPONENT LIST (CONT.)

TAG NO.	DRAWING NO.	SHEET NO.	DRAWING ZONE	NOTES
MANUAL VALVES (CONT.)				
SI-875G	5379-1082	4	F2	1,3
SI-875H	5379-1082	4	F3	1,3
SI-875I	5379-1082	4	D2	1,3
SI-875J	5379-1082	4	D3	1,3
SI-875K	5379-1082	4	C2	1,3
SI-875L	5379-1082	4	C4	1,3
SI-875M	5379-1082	4	B6	1,4
SI-875N	5379-1082	4	B6	1,4
SI-875P	5379-1082	4	B7	1,4
SI-875R	5379-1082	4	A7	1,4
SI-875S	5379-1082	4	B7	1,4
SI-875T	5379-1082	4	A7	1,4
SI-876	5379-1082	4	D5	1,3
SI-876D	5379-1082	4	D4	1,3
SI-876E	5379-1082	4	D4	1,3
SI-878C	5379-1082	2	E7	1,3
SI-881A	5379-1082	5	F6	
SI-881B	5379-1082	5	F6	
SI-881C	5379-1082	5	F5	
SI-881D	5379-1082	5	F5	
SI-881E	5379-1082	5	D6	
SI-881F	5379-1082	5	D6	
SI-881G	5379-1082	5	D5	

TABLE 3-1. COMPONENT LIST (CONT.)

TAG NO.	DRAWING NO.	SHEET NO.	DRAWING ZONE	NOTES
MANUAL VALVES (CONT.)				
SI-881H	5379-1082	5	D5	
SI-881J	5379-1082	5	B6	
SI-881K	5379-1082	5	B6	
SI-881L	5379-1082	5	B5	
SI-881M	5379-1082	5	B5	
SI-882A	5379-1082	5	E6	
SI-882B	5379-1082	5	D6	
SI-882C	5379-1082	5	B6	
SI-883A	5379-1082	5	F5	1,4
SI-883B	5379-1082	5	F6	
SI-883C	5379-1082	5	E5	
SI-883D	5379-1082	5	D6	1,4
SI-883E	5379-1082	5	E6	
SI-883F	5379-1082	5	D5	
SI-883G	5379-1082	5	C5	1,4
SI-883H	5379-1082	5	C6	
SI-883I	5379-1082	5	D6	1,4
SI-883J	5379-1082	5	B5	
SI-883L	5379-1082	1	C6	
SI-883K	5379-1082	1	F5	1,3
SI-883P	5379-1082	1	F5	1,2
SI-883R	5379-1082	4	F6	
SI-883S	5379-1082	1	E5	1,2
SI-883T	5379-1082	5	E4	1,3
SI-883U	5379-1082	5	F6	1,4
SI-883V	5379-1082	5	C4	1,3

TABLE 3-1. COMPONENT LIST (CONT.)

TAG NO.	DRAWING NO.	SHEET NO.	DRAWING ZONE	NOTES
MANUAL VALVES (CONT.)				
SI-883W	5379-1082	1	B5	
SI-883X	5379-1082	5	C6	1,4
SI-884A	5379-1082	4	F2	
SI-884B	5379-1082	4	F4	
SI-884C	5379-1082	4	E2	
SI-884D	5379-1082	4	E4	
SI-884E	5379-1082	4	C2	
SI-884F	5379-1082	4	C4	
SI-885	5379-1082	4	B3	
SI-886A	5379-1082	2	C5	
SI-886B	5379-1082	2	E5	
SI-886C	5379-1082	2	F5	
SI-886D	5379-1082	2	D5	
SI-886E	5379-1082	2	E5	
SI-886F	5379-1082	2	F5	1,4
SI-887	5379-1082	2	C3	
SI-888A	5379-1082	2	C7	
SI-888B	5379-1082	2	E7	
SI-888C	5379-1082	2	F7	
SI-888D	5379-1082	2	B6	1,4
SI-888E	5379-1082	2	B6	1,4
SI-888F	5379-1082	2	C6	1,3
SI-888G	5379-1082	2	C6	1,3
SI-888H	5379-1082	2	E6	1,3
SI-888I	5379-1082	2	E6	1,3
SI-888J	5379-1082	2	B6	1,4
SI-888K	5379-1082	2	B6	1,4
SI-888L	5379-1082	2	F6	1,3

TABLE 3-1. COMPONENT LIST (CONT.)

TAG NO.	DRAWING NO.	SHEET NO.	DRAWING ZONE	NOTES
MANUAL VALVES (CONT.)				
SI-888M	5379-1082	2	F6	1,3
SI-888N	5379-1082	2	B6	1,4
SI-888P	5379-1082	2	E7	1,3
SI-888R	5379-1082	2	D7	1,3
SI-888S	5379-1082	2	C7	1,3
SI-888T	5379-1082	2	C6	1,3
SI-888U	5379-1082	2	D6	1,3
SI-888V	5379-1082	2	F6	1,3
SI-888W	5379-1082	2	B6	1,4
SI-891C	5379-1082	2	D2	
SI-891D	5379-1082	2	D2	
SI-895A	5379-1082	1	G4	1,2
SI-895B	5379-1082	1	G4	1,7
SI-895C	5379-1082	1	G3	1,3
SI-895D	5379-1082	1	F3	1,2
SI-895E	5379-1082	1	D1	1,2
SI-895F	5379-1082	1	G4	1,2
SI-895G	5379-1082	1	G5	1,2
SI-895H	5379-1082	1	D2	1,2
SI-895I	5379-1082	4	E4	1,3
SI-895J	5379-1082	1	D2	1,2
SI-895K	5379-1082	1	C5	
SI-895L	5379-1082	1	D4	1,4
SI-895M	5379-1082	1	D5	1,3
SI-895N	5379-1082	1	E5	1,4
SI-895P	5379-1082	1	G3	
SI-895R	5379-1082	2	F3	1,3
SI-895S	5379-1082	1	E6	1,2

TABLE 3-1. COMPONENT LIST (CONT.)

TAG NO.	DRAWING NO.	SHEET NO.	DRAWING ZONE	NOTES
MANUAL VALVES (CONT.)				
SI-895T	5379-1082	1	B3	
SI-895U	5379-1082	1	F3	
SI-895V	5379-1082	1	G7	
SI-896J	5379-1082	1	G6	1,2
SI-896K	5379-1082	1	G5	1,2
SI-896L	5379-1082	1	E4	1,2,6
SI-896M	5379-1082	1	E4	1,2,6
SI-897G	5379-1082	2	F7	
SI-897K	5379-1082	2	F3	
SI-898A	5379-1082	2	D6	1,2
SI-898B	5379-1082	2	E6	1,2
SI-898C	5379-1082	2	F6	1,2
SI-898D	5379-1082	2	F3	1,7,12
SI-898F	5379-1082	1	G7	
SI-898G	5379-1082	2	D6	
SI-898H	5379-1082	2	E6	
SI-898I	5379-1082	2	F3	1,7
SI-898J	5379-1082	2	G6	
SI-899B	5379-1082	1	B4	
SI-900	5379-1082	5	F2	
SI-901	5379-1082	5	F2	
SI-910	5379-1082	5	F3	1,8
SI-911	5379-1082	5	F3	1,8
SI-912	5379-1082	5	F3	
SI-913A	5379-1082	2	D2	
SI-913B	5379-1082	2	C2	

TABLE 3-1. COMPONENT LIST (CONT.)

TAG NO.	DRAWING NO.	SHEET NO.	DRAWING ZONE	NOTES
ORIFICES				
FE-605	5379-1484	1	D7	
FE-608	5379-1484	1	C5	
FE-932	5379-1082	4	D7	
FE-933	5379-1082	4	D7	
FE-934	5379-1082	1	E4	1,6
FE-940	5379-1082	1	F5	
FE-941	5379-1082	1	G5	
FE-943	5379-1082	1	C2	
ORSI-1	5379-1082	2	D6	
ORSI-2	5379-1082	2	E6	
ORSI-3	5379-1082	2	G6	
RHR - LHSI (line 6-AC-601R-203)	5379-1484	1	E8	
PUMPS				
RHR-A	5379-1484	1	D4	
RHR-B	5379-1484	1	F4	
SI-A	5379-1082	2	C6	
SI-B	5379-1082	2	E6	
SI-C	5379-1082	2	F6	
HEAT EXCHANGERS				
RHR-A	5379-1484	1	D6	
RHR-B	5379-1484	1	F6	
RHR-PUMP A	5379-1484	1	D4	
RHR-PUMP B	5379-1484	1	F4	
SI-PUMP A-1	5379-1082	2	B8	
SI-PUMP A-2	5379-1082	2	B8	
SI-PUMP B-1	5379-1082	2	B8	

TABLE 3-1. COMPONENT LIST (CONT.)

TAG NO.	DRAWING NO.	SHEET NO.	DRAWING ZONE	NOTES
HEAT EXCHANGERS (CONT.)				
SI-PUMP B-2	5379-1082	2	B8	
SI-PUMP C-1	5379-1082	2	B8	
SI-PUMP C-2	5379-1082	2	B8	
VESSELS				
RWST	5379-1082	2	F4	
BIT	5379-1082	1	D5	
SI-ACCUMULATOR A	5379-1082	5	F6	
SI-ACCUMULATOR B	5379-1082	5	D6	
SI-ACCUMULATOR C	5379-1082	5	B6	
INSTRUMENTATION				
FI-608	5379-1484	1	C5	1,5
FI-934	5379-1082	1	E4	1,5,6
FI-941	5379-1082	1	G5	1,5
FT-605	5379-1484	1	D8	
FT-932	5379-1082	4	D8	1,5
FT-933	5379-1082	4	D7	1,5
FT-940	5379-1082	1	G5	1,5
FT-943	5379-1082	1	D2	1,5
LC-934	5379-1082	1	F5	1,5
LIC-947	5379-1082	2	F2	1,5
LT-920	5379-1082	5	F5	1,5
LT-922	5379-1082	5	F7	1,5
LT-924	5379-1082	5	D5	1,5

TABLE 3-1. COMPONENT LIST (CONT.)

TAG NO.	DRAWING NO.	SHEET NO.	DRAWING ZONE	NOTES
INSTRUMENTATION (CONT.)				
LT-926	5379-1082	5	D7	1,5
LT-928	5379-1082	5	B5	1,5
LT-930	5379-1082	5	B7	1,5
LT-948	5379-1082	2	F2	1,5
LT-969	5379-1082	2	F3	1,5
PC-600A	5379-1082	2	C2	
PC-601A	5379-1082	2	D2	
PI-600	5379-1484	1	F4	1,5
PI-600A	5379-1082	2	C2	1,5
PI-601	5379-1484	1	E4	1,5
PI-601A	5379-1082	2	D2	1,5
PI-942	5379-1082	1	G4	1,5
PI-956A	5379-1082	2	D7	1,5
PI-956B	5379-1082	2	E7	1,5
PI-956C	5379-1082	2	F7	1,5
PI-960	5379-1082	5	F2	1,5
PI-961	5379-1082	5	F2	1,5
PT-921	5379-1082	5	F5	1,5
PT-923	5379-1082	5	F7	1,5
PT-925	5379-1082	5	E5	1,5
PT-927	5379-1082	5	E7	1,5
PT-929	5379-1082	5	C5	1,5
PT-931	5379-1082	5	C7	1,5

TABLE 3-1. COMPONENT LIST (CONT.)

TAG NO.	DRAWING NO.	SHEET NO.	DRAWING ZONE	NOTES
INSTRUMENTATION (CONT.)				
PT-934	5379-1082	1	F6	1,5
PT-940	5379-1082	1	G3	1,5
PT-943	5379-1082	1	D1	1,5
PX-956A	5379-1082	2	B6	1,5
PX-956B	5379-1082	2	B6	1,5
PX-956C	5379-1082	2	B6	1,5
TE-604A	5379-1484	1	E5	1,5
TE-604B	5379-1484	1	F5	1,5
TE-606	5379-1484	1	C7	1,5
TI-661A	5379-1484	1	D6	1,5
TI-661B	5379-1484	1	F6	1,5

Notes:

1. Component exempt from FMEA.
2. Root valve to a single instrument.
3. Drain valve.
4. Vent valve.
5. Instrument does not control an active ECCS component.
6. SI pipe blocked by 1 1/4 inch round stock (Mod 888). Component is not functional during ECCS operation.
7. Local sample valve.
8. Test connection valve.
9. Flush line isolation valve.
10. Motor actuators are disconnected electrically.
11. Drain valve locked closed.
12. Sample line valve locked closed.
13. Valve normally closed and not cycled during ECCS operation. Interlocks disable valve operation during ECCS standby operation, injection phase and recirculation phase. Valve external leakage enveloped by line segment FMEA.
14. Mod M-1017 changed RHR-752A and RHR-752B operators from manual operators to motor operators.

4.0 FAILURE MODE AND EFFECTS ANALYSIS GUIDELINES

Section 4.0 presents the guidelines used by the analyst in the preparation of the failure mode and effects analysis (FMEA) of the RNP ECCS. Section 4.1 presents general guidelines used in FMEA preparation. Section 4.2 identifies component failure modes, failure causes, and failure classifications that were considered during the FMEA preparation.

4.1 PREPARATION GUIDELINES

The FMEA was performed in accordance with the guidelines presented in ANSI/IEEE Standard 352-1987 to demonstrate that the ECCS is in compliance with 10CFR50.46 and Appendix K.

The following definitions apply for the SFA.

ECCS Injection Phase - The time immediately following the incident during which, automatic actions are performed, system responses are checked, type of incident is identified, and precautions for long-term recovery operations are made. In the event of a loss-of-coolant accident, the injection mode period (during Emergency Core Cooling System operation) is the basis for the short term period.

ECCS Recirculation Phase - The remainder of the recovery period following the short term. In comparison with the short term where the main concern is to remain within NRC-specified site criteria, the long term period of operation involves bringing the plant to cold shutdown conditions where access to the containment can be gained and repair effected. This period lasts until the containment atmosphere is stable with the ECCS inactive.

Active Failure - The failure of a powered component such as a piece of mechanical equipment, component of the electrical supply system, or instrumentation and control equipment to act on command or the failure of any component that relies on mechanical movement to perform its design function. Examples include the failure of a powered valve to move to its correct position, the failure of a pump, fan or diesel generator to start, the failure of a check valve to change state, etc.

Passive Failure - The structural failure of a static fluid system component which prevents that component from performing its design function. Specifically, a passive failure is identified as a break in the pressure boundary resulting in abnormal leakage not exceeding 50 gpm for the RHR pit. Such leak rates are consistent with limited cracks in pipes, sprung flanges, valve packing leaks or pump seal failures and are credited historically for being the basis of the 50 gpm commitment. Leakage in the Auxiliary Building was limited to quantities as discussed in the UFSAR.

Powered Component - Any mechanical, electrical or instrumentation/control equipment which requires either electrical, hydraulic or pneumatic power to perform its function.

The following ground rules and assumptions were applied to the SFA.

- During the ECCS injection phase, the single failure is limited to a failure of an active component to complete its function as required. During the ECCS recirculation phase the failure definition is expanded to consider either an active failure or a passive fluid system failure without the loss of the system protective function.

- During the recirculation phase, the SFA shall consider the effects of localized flooding resulting from ECCS leakage on ECCS components and support systems required for ECCS operation.

- ECCS equipment qualification for the post-accident environment (e.g., temperature, humidity, spray, submerged operation, and radiation) is not within the scope of this analysis. ECCS and support system equipment which is not normally submerged during a post-accident environment, but which becomes submerged as a result of ECCS leakage shall be evaluated by the SFA.

- Cascading failures resulting from the effects of a single active or passive fluid system failure (when applicable) shall be considered as a single in the SFA evaluation.

- Leakage into and out of the ECCS shall be addressed by the SFA. The effects of outleakage and, when applicable, inleakage shall be considered for the FMEA failure mode 'external leakage.'

- The effects of failures with off-site power available shall be addressed by the SFA.

- Confirmation of the ECCS physical configuration and valve lineup for ECCS standby operation is accomplished by the ECCS DBD preparation and validation and operating procedures for the SI and RHR systems.

- A component failure which causes the ECCS to deliver less than the minimum injection flow requirements into the RCS cold legs (as defined by Appendix K) shall be considered as a potential ECCS single point failure.

- Industry practice does not consider component ruptures (e.g., tanks, pipes, pumps, valves, etc.) as being credible events during the recirculation phase. The maximum credible leak assumed during the recirculation phase shall be 50 gpm for the RHR pit. Leakage into the Auxiliary Building is limited to quantities as discussed in the UFSAR.

4.2 COMPONENT FAILURE MODES

Table 4-1 provides guidelines for the applicable failure modes considered for following component categories:

- Motor operated valve (MOV)
- Air operated valve (AOV), includes solenoid pilot valve
- Check valve
- Manual valve
- Control valve (CV), includes hand, local, remote, and pressure control valves
- Relief valve
- Pump
- Heat exchanger
- Vessel (pressurized)
- Vessel (unpressurized)
- Line segment
- Containment sump
- Orifice
- Bistable unit
- Flow, pressure, level, or temperature switch
- Valve position limit switch
- Torque switch
- Hand switch
- Relay
- Power source/supply
- Switchgear/circuit breaker
- Motor starter contactor
- Fuse

Typical generalized failure causes have been identified for each failure mode. These failure causes include:

- Electrical failure
- Mechanical failure
- Loss of air or nitrogen source

Operator error was considered as an applicable failure mode during the recirculation phase when a pump is required to be manually cycled off/on or when a valve is required to be manually stroked. Table 4-2 presents a listing of ECCS components that require manual operation during the recirculation phase.

For the purpose of this SFA, all electrical component failures and/or electrical failures are designated as 'active failures.'

Table 4-1. Component Failure Modes

Component	Failure Modes	Typical Failure Causes	Failure Class	Remarks
Motor operated valve	Fail open	Electrical failure or mechanical failure	Active	
	Fail closed	Electrical failure or mechanical failure	Active	
	Fail mid-travel	Electrical failure or mechanical failure	Active	
	Internal leakage	Mechanical failure	Passive	
	External leakage	Mechanical failure	Passive	
	Loss of control circuit power	Electrical failure	Active	Identify power source and division (e.g., distribution panel or MCC control transformer (CT)).
	Loss of motive power	Electrical failure	Active	Identify power source and divisions (e.g., MCC and cubicle).
	Valve stem leakoff line plugged or leaks	Mechanical failure	Passive	Failure mode only applicable when valve stem leakoff line is provided.
Air operated valve	Fail open	Electrical failure, mechanical failure, or loss of air/nitrogen source	Active	Identify air supply source if applicable (e.g., safety class and division, BOP).
	Fail closed	Electrical failure, mechanical failure, or loss of air/nitrogen source	Active	Identify air supply source if applicable (e.g., safety class and division, BOP).
	Fail mid-travel	Mechanical failure	Active	

Table 4-1. Component Failure Modes (Continued)

Component	Failure Modes	Typical Failure Causes	Failure Class	Remarks
Air operated valve (Continued)	Internal leakage	Mechanical failure	Passive	
	External leakage	Mechanical failure	Passive	
	Loss of control circuit power	Electrical failure	Active	Identify power source and division (e.g., distribution panel)
	Valve stem leakoff line plugged or leaks	Mechanical failure	Passive	Failure mode only applicable when valve stem leakoff line is provided.
Check valve	Fail to open	Mechanical failure	Active	FMEA will evaluate effect of active failures. Active check valve failures may be exempted if a check valve periodic testing program exists. In addition, active check valve failures are exempted by SI system DBD.
	Fail to close	Mechanical failure	Active	FMEA will evaluate effect of active failures. Active check valve failures may be exempted if a check valve periodic testing program exists. In addition, active check valves are exempted by SI system DBD.
	Fail mid-travel	Mechanical failure	Active	Do not analyze in FMEA. The effects of this failure mode are enveloped by fail to open and fail to close.
	Leakage from system	Mechanical failure	Passive	

Table 4-1. Component Failure Modes (Continued)

Component	Failure Modes	Typical Failure Causes	Failure Class	Remarks
Manual valve	Fail open	Mechanical failure	Active	Applicable if valve stroking required during ECCS operation.
	Fail closed	Mechanical failure	Active	Applicable if valve stroking required during ECCS operation.
	Fail mid-travel	Mechanical failure	Active	Applicable if valve stroking required during ECCS operation.
	Internal leakage	Mechanical failure	Passive	
	External leakage	Mechanical failure	Passive	
	Valve stem leakoff line plugged or leaks	Mechanical failure	Passive	Failure mode only applicable when valve stem leakoff line is provided.
Control valve (hand, local, remote, or PCV)	Fail open	Electrical failure or mechanical failure	Active	Identify control circuit components, electrical power source and division (e.g., distribution panel) if applicable.
	Fail closed	Electrical failure or mechanical failure	Active	Identify control circuit components, electrical power source and division (e.g., distribution panel) if applicable.
	Fail mid-travel	Electrical failure or mechanical failure	Active	

Table 4-1. Component Failure Modes (Continued)

Component	Failure Modes	Typical Failure Causes	Failure Class	Remarks
Control valve (Continued)	Internal leakage	Mechanical failure	Passive	
	External leakage	Mechanical failure	Passive	
	Valve stem leakoff line plugged or leaks v	Mechanical failure	Passive	Failure mode only applicable when alve stem leakoff line is provided.
Relief valve	Fail to open	Mechanical failure	Active	FMEA will evaluate effect of active failures. Active relief valve failures may be exempted if a relief valve periodic testing program exists. In addition, active relief valve failures are exempted by SI system DBD.
	Fail to close	Mechanical failure	Active	FMEA will evaluate effect of active failures. Active relief valve failures may be exempted if a relief valve periodic testing program exists. In addition, active relief valve failures are exempted by SI system DBD.
	Premature Opening	Mechanical failure	Active	FMEA will evaluate effect of active failures. Active relief valve failures may be exempted if a relief valve periodic testing program exists. In addition, active relief valve failures are exempted by SI system DBD.
	Leakage	Mechanical failure	Passive	
Pump	Fail on	Electrical failure	Active	Identify electrical power source and division (e.g., MCC and cubicle).
	Fail to stop on command	Electrical failure	Active	

Table 4-1. Component Failure Modes (Continued)

Component	Failure Modes	Typical Failure Causes	Failure Class	Remarks
Pump (Continued)	Fail off	Electrical failure or mechanical failure	Active	
	Discharge pressure/ flow low	Electrical failure or mechanical failure	Active	
	Leakage from system	Mechanical failure	Passive	
Heat exchanger	Failure to operate (remove heat)	Cooling water supply not available	Active	Identify cooling water source (e.g., CCW Train A). Note: active failure is exempt. All support systems are assumed operational.
	Failure to operate (remove heat)	Internal blockage or plugging	Passive	
	Internal leakage	Mechanical failure	Passive	Identify which way leakage will go. Primary to secondary or secondary to primary.
	Leakage from system	Mechanical failure	Passive	
Vessel(pressurized)	Leak	Mechanical failure	Passive	
	Inventory high	Instrumentation failure	Active	
	Pressure high	Instrumentation failure	Active	
	Pressure low	Instrumentation failure	Active	
	Pressure low	Mechanical failure	Passive	
Vessel (vented)	Leak	Mechanical failure	Passive	
	Inventory high	Instrumentation failure	Active	
	Blocked vent	Mechanical failure	Passive	
	Blocked overflow	Mechanical failure	Passive	
	Inventory low	Instrumentation failure	Active	

Table 4-1. Component Failure Modes (Continued)

Component	Failure Modes	Typical Failure Causes	Failure Class	Remarks
Line segment	Leakage	Mechanical failure	Passive	Worst case passive failure.
Containment sump	Plugging	Mechanical failure	Passive	
Orifice	Leakage from flange	Mechanical failure	Passive	Worst case passive failure.
	Plugging	Mechanical failure	Passive	
Bistable unit	Fails high	Electrical failure or mechanical failure	Active	
	Fails low	Electrical failure or mechanical failure	Active	
	Fails constant	Electrical failure or mechanical failure	Active	
	Loss of power	Electrical failure	Active	Identify power source and division (e.g., distribution panel circuit)
Flow, pressure, level, or temperature switch	Fails high	Electrical failure or mechanical failure	Active	
	Fails low	Electrical failure or mechanical failure	Active	
	Contact set - fails high	Electrical failure or mechanical failure	Active	Analyze each active contact set in switch.
	Contact set - fails low	Electrical failure or mechanical failure	Active	
	Leakage at pressure boundary	Mechanical failure	Passive	

Table 4-1. Component Failure Modes (Continued)

Component	Failure Modes	Typical Failure Causes	Failure Class	Remarks
Valve position limit switch	Contact set - fails open	Electrical failure or mechanical failure	Active	Analyze each active contact set in the control circuit.
	Contact set - fails closed	Electrical failure or mechanical failure	Active	Analyze each active contact set in the control circuit.
	Switch fails to open position	Electrical failure or mechanical failure	Active	
	Switch fails to closed position	Electrical failure or mechanical failure	Active	
	Switch fails to mid-travel position	Electrical failure or mechanical failure	Active	Do not analyze in FMEA. The effects of the failure mode is enveloped the failure modes, switch fails to the open or closed position.
Torque switch	Contact set - fails open	Electrical failure or mechanical failure	Active	Analyze each active contact set in the control circuit.
	Contact set - fails closed	Electrical failure or mechanical failure	Active	Analyze each active contact set in the control circuit.
	Switch fails to the high torque state	Electrical failure or mechanical failure	Active	
	Switch fails to the low torque state	Electrical failure or mechanical failure	Active	

Table 4-1. Component Failure Modes (Continued)

Component	Failure Modes	Typical Failure Causes	Failure Class	Remarks
Switchgear/circuit breaker (Continued)	Partial trip	Electrical failure or mechnical failure	Active	
	Partial closure	Electrical failure or mechanical failure	Active	
	Loss of control power	Electrical failure	Active	Identify power source and division (DC panel).
Motor starter contactor	Fail tripped	Electrical failure or mechanical failure	Active	Identify power source and division (e.g., bus, MCC and cubicle).
	Fail closed	Electrical failure or mechanical failure	Active	
	Partial trip	Electrical failure or mechnical failure	Active	
	Partial closure	Electrical failure or mechanical failure	Active	
	Loss of control power	Electrical failure	Active	Identify power source and division (DC panel, MCC CT).
Fuse	Fail open	Electrical failure	Active	Identify power source and division (e.g., panel and circuit position).
	Fail shorted (fails to blow)	Electrical failure	Active	

Table 4-1. **Component Failure Modes (Continued)**

Component	Failure Modes	Typical Failure Causes	Failure Class	Remarks
Hand switch	Contact set - fails open	Electrical failure or mechanical failure	Active	Analyze each active contact set in the control circuit.
	Contact set - fails closed	Electrical failure or mechanical failure	Active	Analyze each active contact set in the control circuit.
	Switch fails to (in) - position.	Mechanical failure	Active	Analyze for each possible switch position.
Relay	Contact set - fails open	Electrical failure or mechanical failure	Active	Analyze each active contact set in the control circuit.
	Contact set - fails closed	Electrical failure or mechanical failure	Active	Analyze each active contact set in the control circuit.
	Relay fails to energized state	Electrical failure or mechanical failure	Active	
	Relay fails to deenergized state	Electrical failure or mechanical failure	Active	Identify power source and division (e.g., distribution panel circuit).
Power source/supply	Fail off	Electrical failure	Active	Identify power source and division (e.g., bus or MCC and cubicle, distribution panel).
Switchgear/circuit breaker	Fail tripped	Electrical failure or mechanical failure	Active	Identify power source and division r(e.g., bus, MCC and cubicle).
	Fail closed	Electrical failure or mechanical failure	Active	

Table 4-2. Components Manually Operated During Recirculation Phase

Component	Required Operation	Time of Operation
Pumps		
SI pumps (both)	Stop/Restart	Note 1
SI pumps (both)	Stop/Restart	Note 2
RHR pumps (both)	Stop/Restart	Note 1
RHR pumps (both)	Stop/Restart	Note 2
Air Operated Valves		
SI-856 A and B	Close and block closed	Note 1
Motor Operated Valves		
RHR-759A and B	Close	Note 1
RHR-759A and B	Throttle Open	Note 2
SI-860A and B	Open	Note 1
SI-861A and B	Open	Note 1
SI-862A and B	Energize control power and close	Note 1
SI-863A and B	Energize control power, unlock and open	Note 1

Table 4-2. Components Manually Operated During Recirculation Phase (Continued)

Component	Required Operation	Time of Operation
SI-864A and B	Energize control power and close	Note 1
SI-865A, B, and C	Energize control power and close	Note 2
SI-866A and B	Energize control power	Note 1
SI-866A and B	Open	Note 3
SI-869	Energize control power and open	Note 1
SI-870A and B	Close	Note 3
SI-880A, B, C and D	Close	Note 1
Manual Valves		
RHR-743	Unlock and close	Note 1
RHR-757C or D	Close (only one valve)	Note 1
RHR-760	Open	Note 1

Notes:
1. Transfer from cold leg injection phase to cold leg recirculation phase.
2. During initial cold leg recirculation phase.
3. Approximately 18 hours after start of LOCA, transfer from cold leg recirculation to hot and cold leg recirculation.

5.0 FAILURE MODE AND EFFECTS ANALYSIS

Detailed failure mode and effects analyses (FMEAs) were performed for all ECCS components and line segments. The FMEA worksheets were generated using guidelines presented in Section 4.0.

Sections 5.1 through 5.14 present a summary of the FMEA findings by the applicable ECCS component grouping.

5.1 AIR OPERATED VALVES

The AOV FMEA worksheets indicate that the ECCS is vulnerable to postulated AOV single point failures that could cause the system not to achieve the required post-accident minimum performance requirements. These potential single point ECCS vulnerabilities are discussed in Sections 5.1.1 and 5.1.2, and a basis is provided regarding their inapplicability.

5.1.1 SI Accumulator AOVs

The following AOVs isolate the SI accumulator pressure boundary: SI-850A, B, C, D, E and F; SI-851 A, B, and C; SI-852 A, B and C; and SI-853 A, B and C. The valves are all normally closed and fail closed on loss of air or control circuit electric power. External leakage from one of these valves would cause pressure and/or level in the associated SI accumulator to decay. If uncorrected, the accumulator would degrade outside of operating limits. All three accumulators are required to meet the minimum ECCS performance requirements.

During ECCS standby operations, low pressure and level alarms actuate in the control room when the operating limits are approached. The operators are immediately aware of the system status and will shut the plant down in accordance with Tech Spec requirements if each accumulator cannot be maintained operational.

The SFA guidelines designate the failure mode, external leakage from the system, as a passive failure. The SFA must only consider this passive failure mode during the ECCS post-accident recirculation phase. When required to meet the injection performance requirements, the SI accumulators are discharged early in the injection phase and have no functional requirements during the recirculation phase. External leakage of these AOVs is not an applicable ECCS single point failure because:

1. Passive failure modes are not considered during ECCS standby operations or during the injection phase when the SI accumulators are required per NRC guidance.

2. During ECCS standby operations, the failure is quickly detected and corrective action is taken in accordance with Tech Spec requirements.

3. Leakage early in the injection phase does not have a significant impact on the ability of the SI accumulators to meet the minimum performance requirements.

AOV SI-852A, B, and C are normally closed; and the valve positions are checked and verified as closed by OP-202 prior to placing the SI system in service. Also, accumulator level and pressure are checked and recorded once per four hours. During ECCS standby operation or during the ECCS injection phase, a short circuit in the valve hand switch circuit will cause the valve to spuriously open and discharge the accumulator to the reactor coolant drain tank (RCDT). The ECCS cannot meet its design requirements unless all three accumulators are operational.

The drain line to the RCDT is sized at one inch and will limit the initial discharge from the accumulator to approximately 100 to 150 gpm. Per the Tech spec, each accumulator contains a minimum of 825 cubic feet of borated water.

If a conservative 100 gpm average discharge rate was assumed for the entire discharge cycle it would take approximately one hour to discharge the accumulator to the RCDT and overflow to the containment sump. During ECCS standby operations, the failure is immediately detected by accumulator low pressure and level alarms and in accordance with the Tech Spec, the operator would take prompt corrective action to restore the accumulator to operational status or shut the plant down if all accumulators cannot be maintained operational. The fail open failure mode for AOVs SI-852A, B and C is not an applicable ECCS single point failure because:

1. During ECCS standby operations, the failure is quickly detected and corrective action is taken in accordance with Tech Spec requirements.

2. If the failure occurred at the start of the injection phase (i.e., worst case timing for a post-accident failure), the accumulator inventory available for cold leg injection would not be significantly decreased.

5.1.2 AOV FCV-605

Flow Control Valve FCV-605 is normally closed and is open during RHR system normal shutdown cooling operations. The valve fails closed on loss of air or control circuit electric power. When the valve is closed, all LHSI flow is through valve RHR-764 and the in-line orifice that prevents RHR pump runout and possible pump damage during LHSI. If FCV-605 fails open during LHSI, both RHR pumps could be damaged due to pump runout. LHSI would be disabled during the injection phase and the ECCS would be inoperative during the recirculation phase.

OP-201 requires that FCV-605 be closed, the position checked and verified and that the air supply to FCV-605 be isolated, checked and verified prior to plant startup. With the air supply isolated, no control circuit failure can cause the valve to spuriously open. The postulated failure is not credible and thus is not an ECCS single point failure during the ECCS injection phase.

EPP-9 requires that the air supply isolation valve to FCV-605 be opened during the transition between the ECCS injection and recirculation phases. In addition, EPP-9 also requires that either manual valve RHR-757C or D be also closed. If FCV-605 spuriously fails open during the ECCS recirculation phase only one of the RHR pumps would be vulnerable to pump runout conditions. The surviving RHR pump is available to meet ECCS flow requirements. Because either manual valve RHR-757C or D is closed during the recirculation phase, the spurious opening of FCV-605 is not designated as an ECCS single point failure during this period of ECCS operation.

5.1.3 AOVs SI-856A and B

The subject valves are normally open during ECCS standby operations and during the ECCS injection phase. They are closed during the ECCS recirculation phase to isolate the SI pump miniflow line discharge from the RWST. The valves fail open on loss of air or control circuit electrical power and the valve is configured with a handwheel that can be used to close the valve. If either one of these valves failed closed, the SI pump miniflow lines are isolated and there is the potential that both of the operational SI pumps could overheat and fail if the pumps were to operate deadheaded due to high reactor coolant system pressure. A short circuit in the valve handswitch will cause the valve to spuriously close. The postulated AOV control circuit failures are potential ECCS single point failures.

This issue was referred to the DBD Discrepancy Resolution Program. The charging pumps can handle breaks less than one inch, therefore HHSI pumps are not required at all for these breaks. For breaks one inch or greater, Reactor Coolant System depressurization occurs such that it is below HHSI pump shutoff head in about 70 seconds. Calculations show that it would take at least 110 seconds for the fluid temperature in the pumps to rise to a temperature high enough to create steam binding which could affect pump operation. Therefore, this potential single-point vulnerability has been resolved.

5.2 MOTOR OPERATED VALVES

The motor operated valve (MOV) FMEA worksheets indicate that the ECCS is vulnerable to postulated MOV single point failures that could cause the system not to achieve the required post-accident minimum performance requirements. These potential single point ECCS vulnerabilities are discussed in Sections 5.2.1, 5.2.2, and 5.2.3; and a basis is provided regarding their inapplicability.

5.2.1 MOV Control Circuit Failures

The FMEA worksheets identified control circuit failures that would either cause the valve to fail in the unsafe position or that would cause the valve to spuriously reposition from the safe position to the unsafe position. The affected valves and the reasons why these MOV failure modes are not applicable ECCS single point failures are discussed in the following paragraphs.

MOVs SI-862A and B isolate the RHR pump suction line from the RWST. The valves are normally open during ECCS standby operation and during the ECCS injection phase. The valves are closed during the ECCS recirculation phase. If either valve is closed during the injection phase, the LHSI function is disabled and the ECCS cannot meet the minimum performance requirements.

MOVs SI-863A and B isolate the discharge from the RHR heat exchangers to the SI pump and containment spray pump suction lines. The valves are normally closed during standby ECCS operation and the ECCS injection phase and open during the ECCS recirculation phase. If either valve is open during the injection phase, a major portion of the LHSI flow is diverted back to the RHR pump suction. Worst case analysis postulated that the RHR system could not meet the ECCS LHSI flow requirements.

MOVs SI-864A and B isolate the RWST discharge to the SI pump, RHR pump and CS pump suction lines. The valves are normally open during standby ECCS operation and the ECCS injection phase and closed during the ECCS recirculation phase. If either valve is closed during the injection phase, the HHSI and LHSI functions are inoperative. In addition, the SI and RHR pumps would be damaged.

MOVs SI-865A, B and C isolate the injection line from each SI accumulator. The valves are normally open when RCS pressure is greater than 1000 psig and normally closed when RCS pressure is approaching or less than the SI accumulator blanket pressure. If one of the valves is closed during the ECCS injection phase, the associated accumulator is isolated and the SI accumulators cannot meet the minimum ECCS requirements. In addition, external leakage from any of the valves would cause pressure and level in the associated accumulator to decay.

The ECCS cannot meet its design requirements unless all three accumulators are operational. See Section 5.1.1 for a detailed discussion on the failure effects and for the rationale for not classifying external leakage of SI-865A, B or C as applicable ECCS single point failures.

MOV SI-878A isolates SI pump B and C discharge manifold from the HHSI cold leg injection flow paths. The valve is normally open during the standby ECCS operations and HHSI operations. Worst case analysis postulated that SI pump A was out of service and SI pump B was racked in and aligned to replace SI pump A. If MOV SI-878A fails closed, both operable SI pumps are isolated from the HHSI cold leg injection flow paths.

Control circuit failures that would either cause the above discussed MOVs to fail in the unsafe position or cause the valve to spuriously reposition from the safe position to the unsafe position during ECCS standby operations are not considered credible. OP-202 requires that all of the subject valves be in the safe position, and the position checked and independently verified before the SI system is placed in standby service. In addition, the Tech Spec requires that the valves be in the safe position and control power removed when RCS pressure is in excess of 1000 psig.

If one of the subject valves was not in the safe position, the plant would not be brought up to operating power. When control power is removed from the valves, the valves are not vulnerable to spurious operation. Therefore these MOV failure modes are not applicable ECCS single point failures.

5.2.2 MOVs SI-868A, B and C

The subject valves isolate each of the HHSI cold leg injection lines. The valves are normally locked open during all modes of plant operation. If any valve is closed during ECCS operation, the ECCS cannot meet the minimum performance requirements unless the cause of ECCS operation is a large break LOCA in the associated cold leg.

The failure of MOV SI-868A, B or C in the closed position is not considered credible. The motor to each of the valves exists in the field but has been disconnected. The valve cannot be electrically actuated and is locked open. OP-202 requires that SI-868A, B and C be locked open, checked and verified before the SI system is placed in service. Therefore, the postulated non-credible failure of the valve (i.e., fail closed) is not an applicable ECCS single point failure.

5.2.3 MOV SI-869

MOV-SI-869 isolates the HHSI hot leg injection flow paths, the accumulator fill lines, and the SI pump flow test lines. The valve is normally closed and is opened for SI pump test, accumulator fill operations, and prior to the start of the ECCS recirculation phase. If MOV SI-869 fails closed, hot leg HHSI is disabled during the recirculation phase.

During ECCS standby operations, the valve is cycled during SI pump flow testing and accumulator fill operations. Failure of the valve would be detected at that time and repair action could be taken. SI-869 is not required to be operational by Technical Specification to support hot leg injection. If the valve can be manually operated by the handwheel to support Technical Specification requirements for SI pump testing and maintenance of accumulator level above the minimum level, Technical Specification LCO conditions will not initiate repair of the valve or other compensatory measures (e.g., shut the plant down).

If the valve cannot be opened from the control room prior to the start of the recirculation phase, EPP-9 directs the operator to use the valve handwheel to open the valve. Prior to start of the recirculation phase, the valve is not located in a high radiation area. Since cycling the valve during normal ECCS standby operations demonstrates that no structural valve failure exists that would prohibit manual operation of the valve, failure of the valve to open prior to the recirculation phase is not considered credible.

During the hot leg recirculation phase, EPP-10 does not require valve SI-869 to close unless one RHR pump is not available for service. In the event that SI-869 cannot be closed from the control room, valves SI-866A and SI-866B are available to isolate the hot leg injection lines. If a failure causes SI-869 to spuriously close during the hot leg recirculation phase, hot leg injection is disabled. Technical Specification Section 3.3.1.2.e states, "The hot leg injection paths of the Safety Injection System, including valves, are not subject to the requirements of this specification." Therefore, the failure of valve SI-869 is not an applicable ECCS single point failure.

5.3 HAND CONTROL VALVES

The hand control valve (HCV) FMEA worksheets indicate that the ECCS is vulnerable to postulated HCV-758 and valve control failures that could result in the loss of both RHR pumps and thus the ECCS could not achieve the required post-accident minimum performance requirements.

The FMEA worksheets identified valve control component failure modes that would cause the valve to spuriously open. If the valve is open during LHSI, the RHR pump discharge is not limited by the LHSI inline orifice. The orifice protects against pump damage due to pump runout. HCV-758 fails closed on loss of air. OP-201 requires that valve HCV-758 be closed and the air supply to the valve be isolated, checked and verified when aligning the RHR system for LHSI prior to startup.

If the valve was failed in the open position and could not be closed, the plant would not be brought up to operating power. When the air supply is isolated from the valve, it is not vulnerable to control component failures that would cause the valve to spuriously open. Therefore the postulated non-credible failure modes are not applicable ECCS single point failures during the ECCS injection phase.

EPP-9 requires that the air supply isolation valve to HCV-758 be opened during the transition between the ECCS cold leg injection and recirculation phases. In addition, EPP-9 also requires that MOVs RHR-759A and B be closed during the initial portion of the ECCS cold leg recirculation phase. When MOVs RHR-759A and B are closed, the RHR pump discharge is isolated from HCV-758. Therefore, the failure of HCV-758 during this period will have no effect on ECCS operation.

Approximately 18 hours after the onset of ECCS operation, EPP-10 requires that the ECCS be realigned to provide hot and cold leg injection during the recirculation phase. After realignment, the RHR pumps provide cold leg LHSI and the suction supply to the SI pumps which are providing hot leg injection. During recirculation phase transition from cold leg injection to hot and cold leg injection, EPP-10 requires that RHR-759A and B be sequentially throttled open to limit LHSI flow to a total of 2250 gpm.

If HCV-758 failed open during this period, the partially opened MOVs RHR-759A and B would limit RHR pump discharge to less than pump runout conditions. Therefore, the failure of HCV-758 during the recirculation phase will have no effect on ECCS operation.

5.4 PRESSURE CONTROL VALVES

The pressure control valve (PCV) FMEA worksheets indicate that the ECCS is not vulnerable to postulated PCV single point failures that could cause the system not to achieve the required post-accident minimum performance requirements.

5.5 CHECK VALVES

The check valve (CV) FMEA worksheets indicate that the ECCS is vulnerable to postulated CV single point failures that could cause the system not to achieve the required post-accident minimum performance requirements. The potential single point ECCS vulnerabilities are discussed in Sections 5.5.1 and 5.5.2, and a basis is provided regarding their inapplicability.

5.5.1 Active Failure Mode

The FMEA worksheets identified active CV failures that would cause the ECCS not to achieve the required post-accident minimum performance requirements. Active check valve failures are exempted if a check valve periodic test program exists. In addition, the SI system DBD has excluded check valves from consideration as active failures. All of the check valves are discussed in Section 5.5.1 are in a periodic testing program. Therefore, the postulated active CV failures are not applicable ECCS single point failures. The affected CVs are discussed in the following paragraphs.

CV SI-839 prevents backflow to the SI pumps when the CS pumps are being tested. If the valve fails closed, the SI pump miniflow return line to the RWST is blocked. During the injection phase, both online SI pumps would overheat and fail if the pumps were to operate deadheaded due to high reactor coolant system pressure. OST-151, "Safety Injection System Component Test," requires that the valve be tested quarterly.

CV SI-873A, B, C, D, E and F isolate the three HHSI cold leg injection lines. Valves A or D isolate loop 3, valves B or E isolate loop 2 and valves C or F isolate loop 1. If any one of the valves fail closed, HHSI is not available for the associated loop. OST-154, "Safety Injection System High Head Check Valve Test," requires that the valves be tested at refueling intervals.

CV SI-874 A and B isolate the hot leg HHSI to loops 3 and 2 respectively. If one of the valves fails closed, HHSI is not available to the associated hot leg. OST-154, "Safety Injection High Head Check Valve Test," requires that the valves be tested at refueling intervals.

CV SI-875D, E and F isolate the discharge line from each SI accumulator. If one of the valves fails closed during the ECCS injection phase, the associated accumulator is isolated and the SI accumulators cannot meet the minimum ECCS requirements. OST-161, "Accumulator Isolation and Check Valve Operability Test," requires that the valves be tested during cold shutdown.

CV SI-875A, B and C isolate the cold leg injection lines from the RCS pressure boundary. If one of the valves fails closed during ECCS operation, the associated cold leg is isolated and the system cannot meet the minimum ECCS requirements. OST-255, "RHR and SI System Check Valve Test," requires that the valves be tested at refueling intervals.

CV SI-876A, B and C isolate the LHSI discharge from each cold leg injection path. If one of the valves fails closed during the ECCS operation, the associated cold leg is isolated from LHSI and the system cannot meet the minimum ECCS requirements. OST-255, "RHR and SI System Check Valve Test," requires that the valves be tested at refueling intervals.

CV SI-879A, B and C isolate the discharge from each SI pump. If the valve on the out of service pump fails open during HHSI operation, worst case analysis postulated that backflow through the inactive pump would prevent the HPSI function from meeting the minimum ECCS requirements. OST-151, "Safety Injection System Component Test," requires that the valves be tested quarterly.

5.5.2 SI Accumulator CVs

The following CVs are within the SI accumulator pressure boundary: SI-875A, B, C, D, E and F; SI-876A, B and C; and SI-877A, B and C. External leakage from any of the valves would cause pressure and level decay in the associated accumulator. The ECCS cannot meet its design requirements unless all three accumulators are operational. See Section 5.1.1 for a detailed discussion on the failure effects and for the rationale for not classifying CV external leakage as applicable ECCS single point failures.

5.6 RELIEF VALVES

The relief valves (RV) FMEA worksheets indicate that the ECCS is vulnerable to postulated RV active single point failures that could cause the system not to achieve the required post-accident minimum performance requirements.

RV SI-858A, B and C relieve overpressurization of each of the SI accumulators due to RCS in leakage, charging/fill operations, and changes in local environmental conditions. If the RV failed to close or had external leakage, the accumulator pressure would decay below operational limits. All three SI accumulators are required to be operational to meet the minimum ECCS performance requirements.

The external leakage and failure to close of RVs SI-858A, B or C are not designated as applicable ECCS single failures. See Section 5.1.1 for a detailed discussion on the failure effects and the rationale for not classifying these failure modes of RVs SI-858A, B or C as applicable ECCS single failures.

5.7 MANUAL VALVES

The manual valve (MV) FMEA worksheets indicate that the ECCS is vulnerable to postulated MV failures that could cause the system not to achieve the required post-accident minimum performance requirements. The potential single point ECCS vulnerabilities are discussed in Sections 5.7.1 and 5.7.2, and a basis is provided regarding their inapplicability.

5.7.1 Mispositioned MVs

The FMEA worksheets identified mispositioned MVs that would cause the ECCS not to achieve the post-accident minimum performance requirements. The affected valves and the reasons why these mispositioned MV failure modes are not applicable ECCS single point failures are discussed in the following paragraphs.

MV RHR-743 isolates the mini flow path for both RHR pumps. If the valve fails closed, both RHR pumps could overheat and become inoperative if LHSI flow was not adequate to cool the pumps. The valve is locked open during power operations.

MV RHR-764 isolates the RHR LHSI flow from the cold leg injection lines. If the valve fails closed, LHSI is disabled. The valve is normally closed during shutdown operations and when the RHR system is aligned for LHSI prior to startup, the valve is locked open.

MV SI-891C and D isolate the alternate discharge flow paths from the RHR heat exchangers to the SI pump and containment spray pump suction lines. The valves are normally locked closed. If either valve is open during the ECCS injection phase, a major portion of the LHSI flow is diverted back to the RHR pump suction; and the RHR system may not meet the ECCS LHSI flow requirements.

MV SI-895K is normally closed and isolates the SI test line from the HHSI line after MOVs SI-867A and B. If the valve is open, a significant portion of the HHSI flow would be diverted back to the SI test line; and the HHSI may not meet the minimum ECCS performance requirements.

The postulated failures (i.e., valve in unsafe position) is not considered credible because OP-201 and OP-202 require that the subject valves be in the safe position, checked and verified prior to placing the SI system in service. Therefore, the postulated failure modes are not applicable ECCS single point failures.

5.7.2 SI Accumulator MVs

The following MVs are within the SI accumulator pressure boundary: SI-881A, B, C, D, E, F, G, H, J, K, L and M; SI-882A, B and C; SI-883B, C, E, F, H, and J; and SI-884A, B, C, D, E and F. External leakage from any of the valves would cause pressure and/or level decay in the associated accumulator.

The ECCS cannot meet its design requirements unless all three accumulators are operational. For reasons detailed in Section 5.1.1, the potential single point vulnerabilities for MV external leakage are not classified as applicable ECCS single failures.

5.8 ORIFICES

Plugging of an orifice is a passive failure mode and is excluded from consideration as an applicable failure during the ECCS injection phase. Passive failure modes are only considered applicable during the ECCS recirculation phase. The orifice FMEA worksheets indicate that the ECCS is not vulnerable to postulated plugging of orifice failures that could cause the system not to achieve the required post-accident minimum performance requirements.

5.9 PUMPS

The pump FMEA worksheets indicate that the ECCS is vulnerable to SI pump B (SIPB) breaker control circuit failures and/or SI actuation signal failures that could result in the loss of buses E1 and E2. With the loss of buses E1 and E2, the ECCS is inoperative.

Control circuit failures in SIPB breakers 52/22B and 52/29B could result in the spurious cross tie of buses E1 and E2. Since the buses and loads would not necessarily be synchronized, worst case analysis postulated that both buses faulted and disabled the ECCS.

The postulated failure mode is not considered credible. OP-202 requires that SIPB breakers 52/22B and 52/29B be racked out when SIPB is not in service. When SIPB is aligned as a replacement pump for SIPA or SIPC, the SIPA or SIPC breaker is racked out and either SIPB breaker 52/22B for SIPA replacement, or breaker 52/29B, for SIPC replacement, is racked in. OP-202 also requires that if breaker 52/22B is racked in, breaker 52/29B is verified as racked out and if breaker 52/29B is racked in, breaker 52/22B is verified as racked out.

Without both breakers 52/22B and 52/29B racked in, there is no control circuit fault or combination of SI actuation signals that will result in the crosstie of buses E1 and E2. Therefore, the postulated failures are not applicable ECCS single point failures.

5.10 HEAT EXCHANGERS

The heat exchanger (HX) FMEA worksheets indicate that the ECCS is not vulnerable to postulated HX single point failures that could cause the system not to achieve the required post-accident minimum performance requirements.

5.11 VESSELS

The vessel FMEA worksheets indicate that the ECCS is vulnerable to postulated vessel single point failures that could cause the system not to achieve the required post-accident minimum performance requirements. These potential single point ECCS vulnerabilities are discussed in Sections 5.11.1 and 5.11.2, and a basis is provided regarding their inapplicability.

5.11.1 RWST

The RWST inventory provides the suction supply to the RHR, SI and containment spray pumps during the ECCS injection phase. If the RWST vent is plugged, a vacuum may result in the tank during ECCS operation and reduce the NPSH available for operation of the ECCS pumps. Worst case analysis postulated that the available NPSH is not adequate for ECCS pump operation during the injection phase. No inspection program has been identified that would detect the plugged vent.

Plugging or blockage of the RWST vent is a passive failure mode and is excluded from consideration as an applicable failure during the ECCS injection phase. Passive failure modes are only considered applicable during the ECCS recirculation phase. Since the RWST is only required for ECCS operation during the injection phase, the postulated failure is not an applicable ECCS single point failure.

5.11.2 SI Accumulators A, B and C

The inventory from all three accumulators is required to be injected into the cold leg injection paths to meet the minimum ECCS performance requirements. Two postulated failure modes, external leakage and fluid inventory high, will prevent the accumulator meeting the minimum ECCS performance requirements. See Section 5.1.1 for a detailed discussion of the failure from effects and the rationale for not classifying this failure mode as an applicable ECCS single point failure.

If the fluid inventory in the accumulator is too high, there is not enough stored energy in the nitrogen blanket pressure to discharge the required volume of the fluid inventory into the cold leg injection flow path. The postulated failure mode, high inventory, can only occur during fill operations or when local environmental conditions cause the inventory to swell and exceed the maximum allowable level. High level alarms actuate in the control room when the operating limit is approached. The operators are immediately aware of the system status and will shut the plant down in accordance with Tech Spec requirements if each accumulator cannot be maintained operational. This failure mode is only applicable when the ECCS is in standby status. During the injection phase, the accumulator level decreases as a function of the RCS pressure and therefore the failure mode is not credible unless the condition existed at the start of the phase. The failure mode is not considered as credible because during ECCS standby operations, the postulated failure is quickly detected and corrective action is taken in accordance with Tech Spec requirements. Therefore, the postulated failure mode (i.e., inventory high) is not an applicable ECCS single point failure.

5.12 CONTAINMENT SUMP

The containment sump FMEA worksheets indicate that the ECCS is not vulnerable to postulated containment sump single point failures that could cause the system not to achieve the required post-accident minimum performance requirements during the ECCS recirculation phase.

5.13 LINE SEGMENTS

The line segment FMEA worksheets indicate that the ECCS is not vulnerable to postulated line segment single point failures that could cause the system not to achieve the required post-accident minimum performance requirements during the ECCS recirculation phase.

5.14 INSTRUMENTATION

The instrumentation FMEA worksheets indicate that the ECCS is not vulnerable to postulated instrumentation single point failures that could cause the system not to achieve the required post-accident minimum performance requirements.

6.0 LOCALIZED FLOODING ASSESSMENT

The ECCS equipment is installed in the following plant areas.

1. SIS Room
2. BIT Room
3. Pipe Alley
4. RHR HX Room
5. RHR Pump Pit
6. Containment (Outside Missile Barrier)
7. Containment (Inside Missile Barrier)
8. Outside (RWST Area)

Areas 1 through 7 were walked down and surveyed to verify that floor drains were available, functional, and capable of draining design ECCS leakage. (Area 8 does not have floor drains.) The purpose of the survey was to identify if there is a potential for localized flooding that could disable ECCS-related equipment located in this area.

The walkdown and survey indicated that at least one floor drain exists in areas 1, 2, 3, 4, 6, and 7. Calculations were performed and verified that any single floor drain and the associated drain lines were capable of handling design ECCS leakage.

6.1 AUXILIARY BUILDING

The floor drains in the auxiliary building are piped to the auxiliary building sump Tank A. The sump tank has a very limited capacity. There is a 300-gallon capacity available after the sump pumps have pumped out the tank. The tank is vented and has 3/4-inch overflow line to the tank room (below grade) floor. If normal equipment leakage of 2277 cc/hr. (based on UFSAR Table 6.3.2-7) occurs, it would take more than 20 days to fill the sump tanks, even if the sump pumps could not be made available. This amount of leakage is not considered to pose a flooding problem in the auxiliary building.

6.2 RHR PUMP PIT

No floor drains exist in the RHR pump pit. All leakage will go to the pit sump. Normally, two 100-gpm sump pumps are available to pump the sump inventory to the WHUT in the auxiliary building. RNP operating procedures reserve 1500 gallons of the WHUT capacity to accept leakage pumped out of the RHR pump pit. If offsite power was available and the sump pumps were operational, the leak in the pit would have to be detected, located, and isolated in less than 30 minutes or WHUT could overflow in the auxiliary building. However, the sump pumps are not available following loss of offsite power. During the ECCS recirculation phase, leakage in the pump pit will ultimately flood both RHR pumps and disable the ECCS.

A modification installed during Refueling Outage 13 (1990-1991) provides for remotely detecting and isolating RHR pump pit ECCS and support system leaks with equipment qualified to operate in the post-accident environment. After the leak has been isolated in accordance with EPP-24, one RHR pump will remain operational.

6.3 CONTAINMENT

The containment floor drains are routed to the containment sump. Localized flooding will not be caused by ECCS leakage at a rate up to 50 gpm. Any localized flooding is the direct result of the LOCA effects. These effects have been previously evaluated and are not within the scope of this analysis.

ECCS leakage up to 50 gpm within the containment will not have any effect on ECCS operation during the recirculation phase.

6.4 RWST AREA

The RWST is located outside of the auxiliary building. ECCS leakage in the RWST area is released directly to the environment. During the ECCS recirculation phase, the RWST is isolated from all ECCS flow paths. Therefore, ECCS leakage in this area is not considered credible.